SLD-Kirkwood 2000

Lessons Learned ^by me, anyway^ from

VXDalone Tracking

Or: How I Learned to Stop Worrying and love Short-Lever-Arm Tracking.

Aaron Chou, Stanford University
(representing the tracking group)

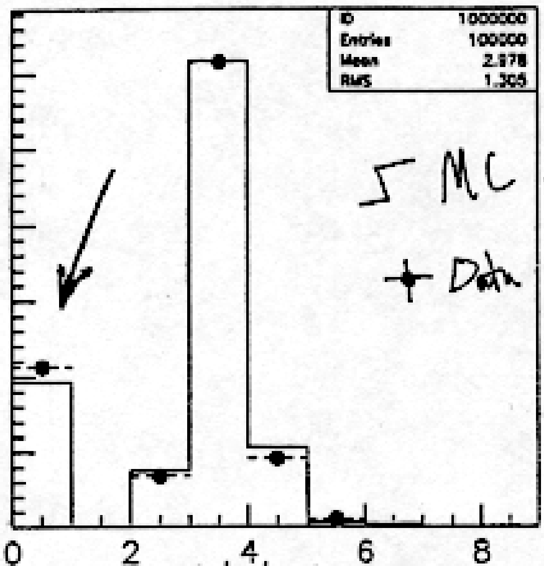
Why use vertex-only vectors? <u>Recover unlinked tracks.</u>

— Better B/D charge reconstruction

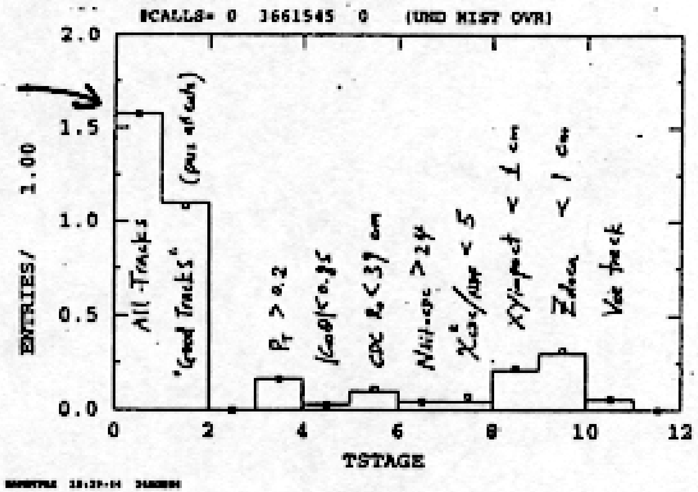
— Better IP→B→D topology reconstruction

— ~~Perhaps~~ Better Kinematics (especially with Leon's PHVXOV ⟺ PHCHRG linking)

→ May fix Data/MC tracking ε mismatch:
(due mainly to linking ε ?)



Nvhit in VXD3, for all PHCHRG tracks



Inefficiencies may be due to Tk Quality Cuts.
The biggest quality cut is requiring VXD3 hits on the track.

→ Precursor to LCD tracking study

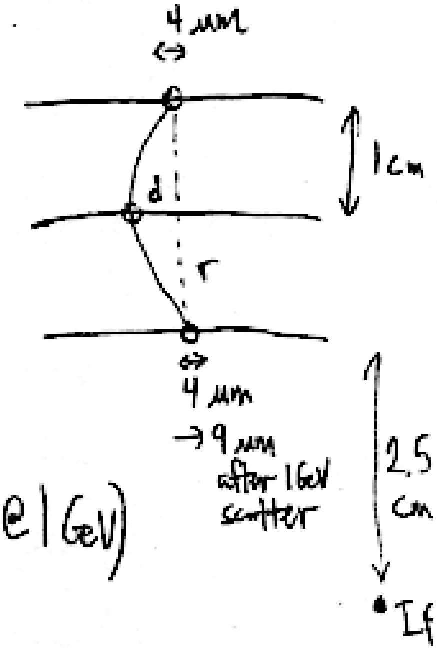
1. Some geometry

2. MC Studies of Charge measurement

3. Data/MC Comparison

4. Vertexing

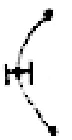
Some Geometry



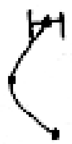
Measure curvature $K = \frac{1}{R_c}$ using parabolic approx.

$$X = \frac{1}{2} K \cdot y^2 \Rightarrow K = \frac{2 \cdot d}{r^2}$$

xy view

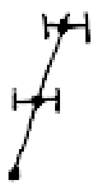


$$\Delta K = \frac{2 \cdot (4\ \mathrm{um})}{(1\ \mathrm{cm})^2} = 8\ \mathrm{u/cm^2} \quad (12\ \mathrm{u/cm^2}\ @\ 1\ \mathrm{GeV})$$



$$\Delta\phi = 4\ \mathrm{u/cm} \quad (12.5\ \mathrm{u/cm}\ @\ 1\ \mathrm{GeV})$$

rz view



$$\Delta\lambda = \left(\left(\frac{4\ \mathrm{um}}{1\ \mathrm{cm}}\right)^2 + \left(\frac{4\ \mathrm{um}}{2\ \mathrm{cm}}\right)^2\right)^{\frac{1}{2}} = 4.5\ \mathrm{um/cm} \quad (10.5\ \mathrm{um/cm}\ 1\,\mathrm{GeV})$$

Impact Params:

xy:
$$\Delta\xi = \Delta\xi_0 + s \cdot \Delta\phi + \tfrac{1}{2} s^2 \cdot \Delta K$$
$$= 4\ \mathrm{um} + (2.5\ \mathrm{cm})\left(\frac{4\ \mathrm{um}}{\mathrm{cm}}\right) + \tfrac{1}{2}(2.5\ \mathrm{cm})^2 \left(8\ \mathrm{um/cm^2}\right)$$
$$\Delta\xi = 39\ \mathrm{um} \quad (73\ \mathrm{um}\ @\ 1\ \mathrm{GeV})$$

rz:
$$\Delta\eta = \Delta\eta_0 + s \cdot \Delta\lambda = 4\ \mathrm{um} + (3\ \mathrm{cm})\left(4.5\ \frac{\mathrm{um}}{\mathrm{cm}}\right)$$
$$\Delta\eta = 17.5\ \mathrm{um} \quad (36\ \mathrm{um}\ @\ 1\ \mathrm{GeV})$$

Momentum:
$$\Delta\frac{Q}{P_T} = \frac{1}{B}\Delta K \simeq 0.44\ \mathrm{c/GeV} \quad (0.67\ \mathrm{c/GeV}\ @\ 1\ \mathrm{GeV})$$

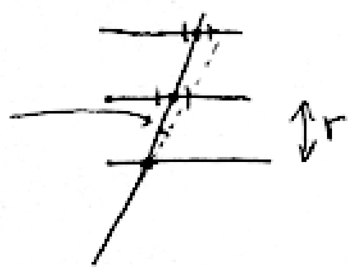
What have we (I) learned?

- 3 hits = 6 transverse measurements

  ⇒ 2 positions, 2 angles, 1 curvature + 1 d.o.f

- Angle measurements are quickly dominated by scattering.

$$\Delta\lambda = \frac{\sqrt{\Delta_0^2 + (\theta_{ms} \cdot r)^2}}{r} \simeq \theta_{ms}$$



- Curvature measurement can be controlled by increasing layer spacing

$$\Delta K \simeq \frac{2\sqrt{\Delta_0^2 + (\theta_{ms} \cdot \frac{r}{2})^2}}{r^2} \simeq \frac{\theta_{ms}}{2r}$$

← Function of measured curvature! Feeds back into errors:

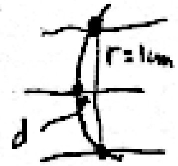
$$\Delta(\Delta\lambda) = \Delta\theta_{ms} \propto \Delta K$$

- Having extra layers helps, gives χ^2 for bkgd rejection
  - 'Scattered' hits get less weight.
  - Extra curvature info may help with alignment

p_T resolution Problem

$$\frac{1}{R_c} = \frac{QB}{p_T} = \frac{(3\times10^{-4})\cdot 6}{p_T} = \frac{2d}{r^2}$$

– High p_T tracks are very straight,



$$d \approx \frac{9\ \mu m}{p_T}$$

A. $p_T = 2$ GeV track will have $d \approx 4\ \mu m$.

But the cluster resolution is also $\Delta d \approx 4\ \mu m$.

$\Rightarrow$ The intrinsic $\frac{1}{p_T}$ resolution is $\Delta\frac{1}{p_T} \approx \frac{1}{2}$ GeV^{-1}

$\Rightarrow$ High p_T tracks will have their p_T smeared down to 2 GeV, (and get the wrong charge)

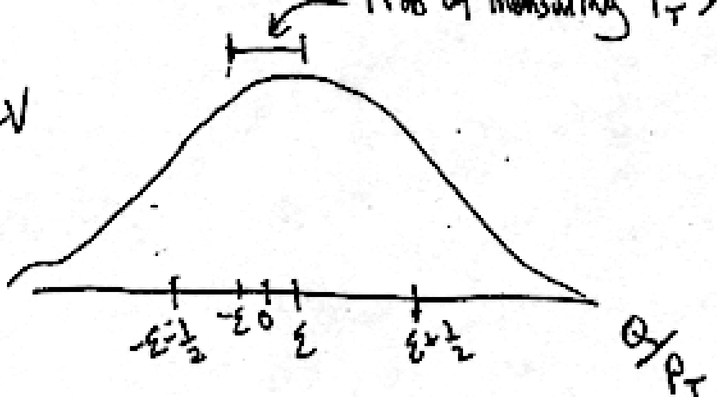
$$\Delta\frac{Q}{p_T} \approx \pm\frac{1}{2}\ \text{GeV}^{-1}$$

Example: High p_T tracks

$\varepsilon = \frac{Q}{p_{T\,true}}$

$p_{T\,true} > 2$ GeV

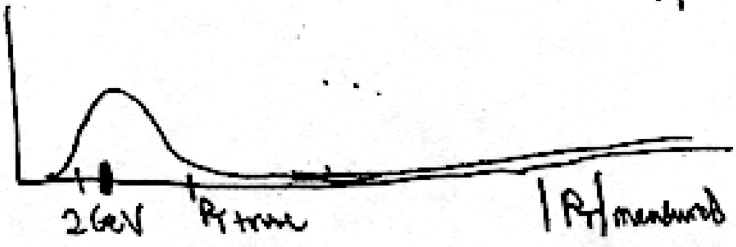
Prob of measuring $p_T > p_{T\,true} \approx \frac{1}{\sqrt{2\pi}\,\sigma}\cdot 2\varepsilon \approx \frac{\varepsilon}{\sigma} \approx 2\varepsilon$



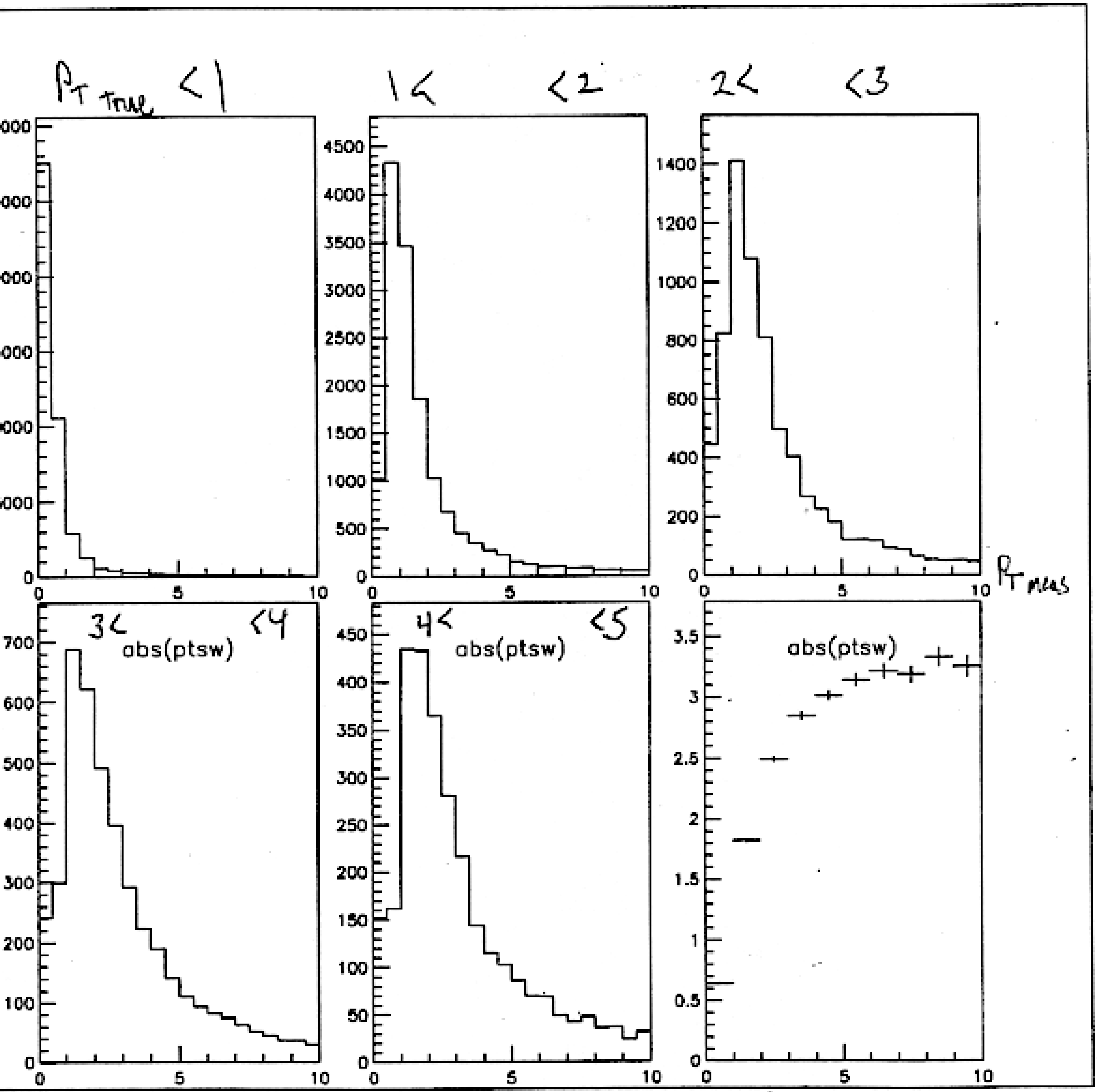
Prob $p_T < p_{T\,true} \approx 1 - 2\varepsilon$

Prob right sign $\approx \frac{1}{2} + \varepsilon$

p_T| distribution $\Rightarrow$



Measured P_T distributions as Fcn of True P_T

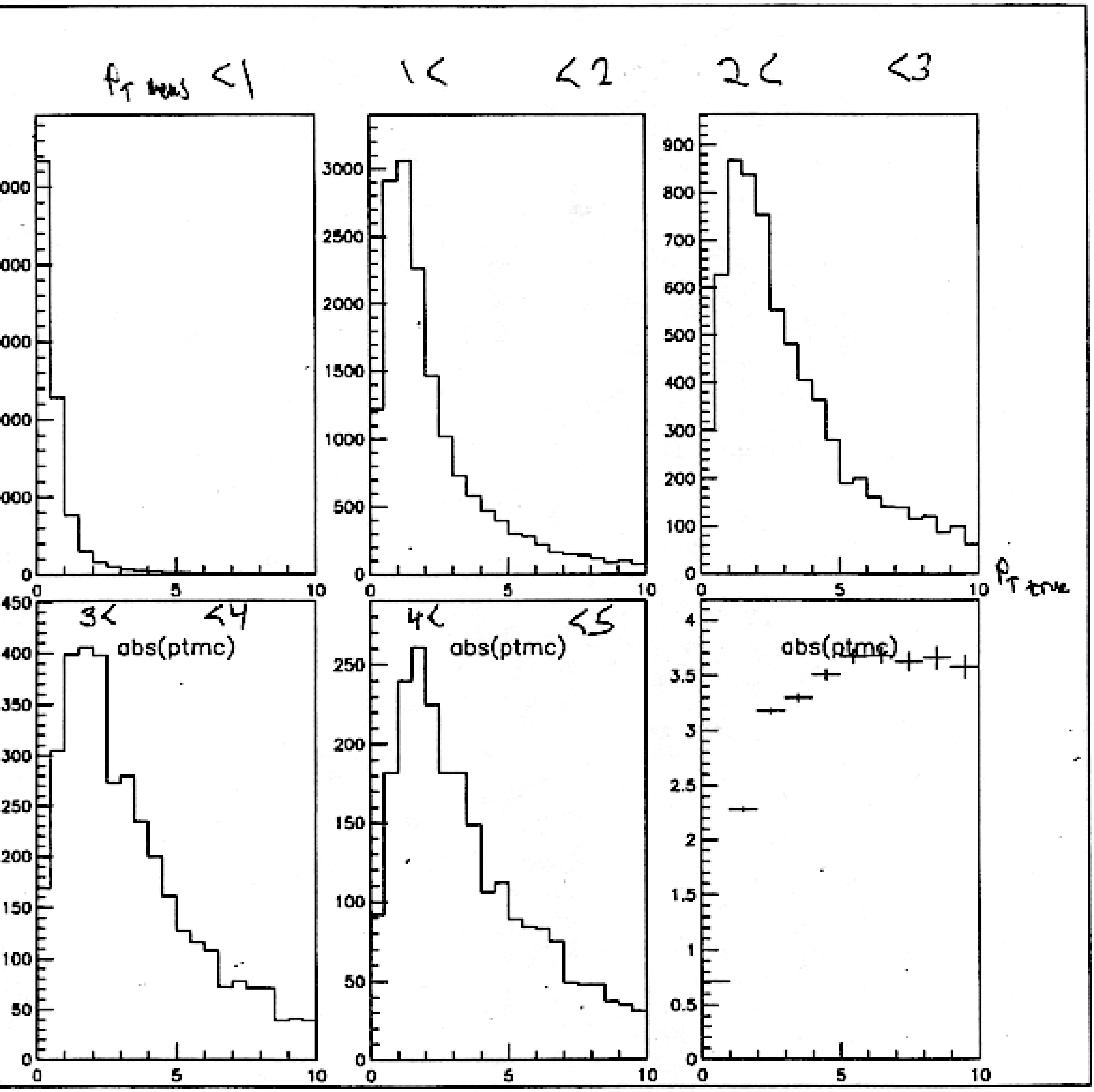


$\langle P_{T\,meas} \rangle$ vs $P_{T\,true}$

⇒ High P_T tracks are smeared down to ~ 2 GeV/c

⇒ Low P_T tracks have a long tail and are often measured at much higher P_T (thus, scattering errors are underestimated)

True p_T distributions as fcn of measured p_T



$\langle p_{T\,true} \rangle$ vs $p_{T\,meas}$

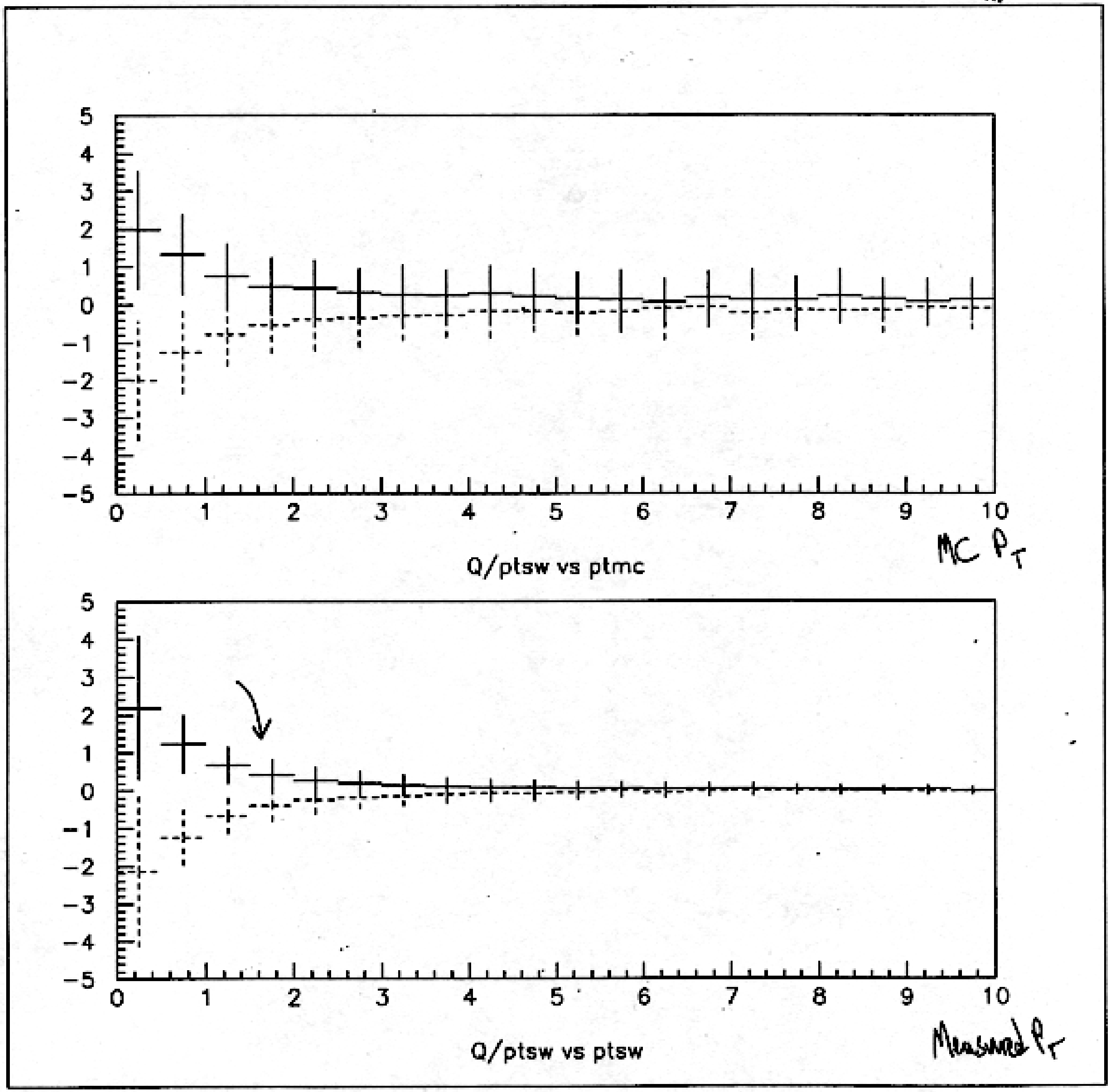
⇒ Measured p_T is not a good estimator of true p_T

(except at low p_T)

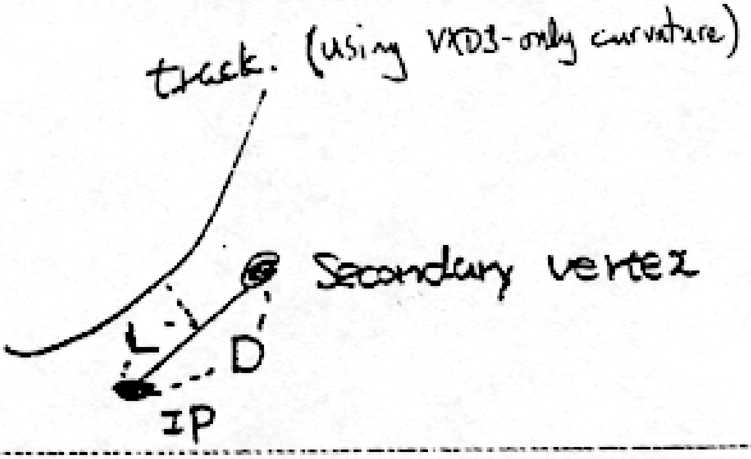
$p_T < 1/(\Delta \frac{q}{p_T})$

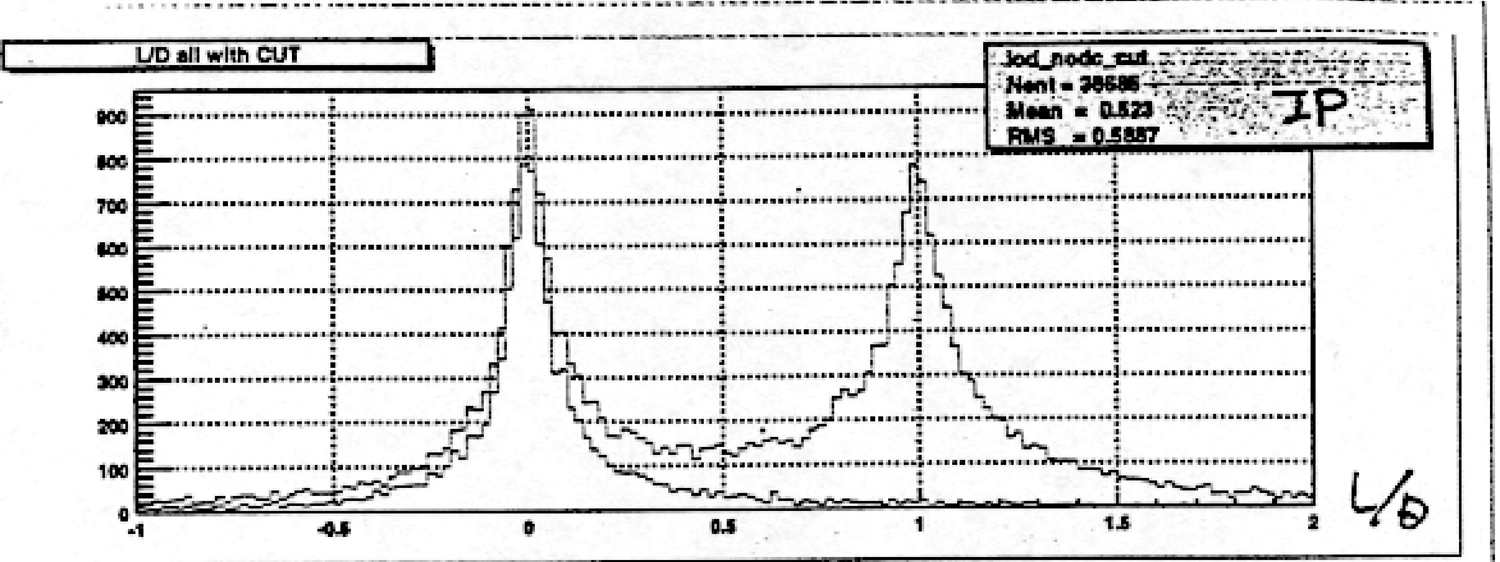
PHVXOV - only Charge Seperation

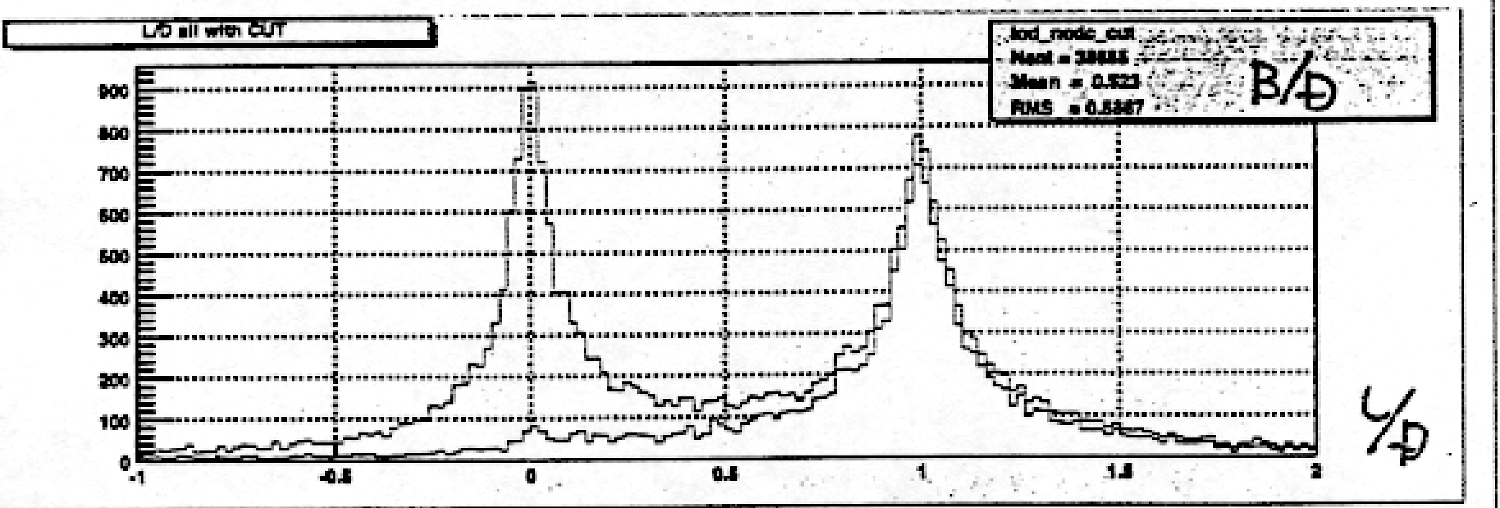
$P_{T_{swim}} > 0.25$ G

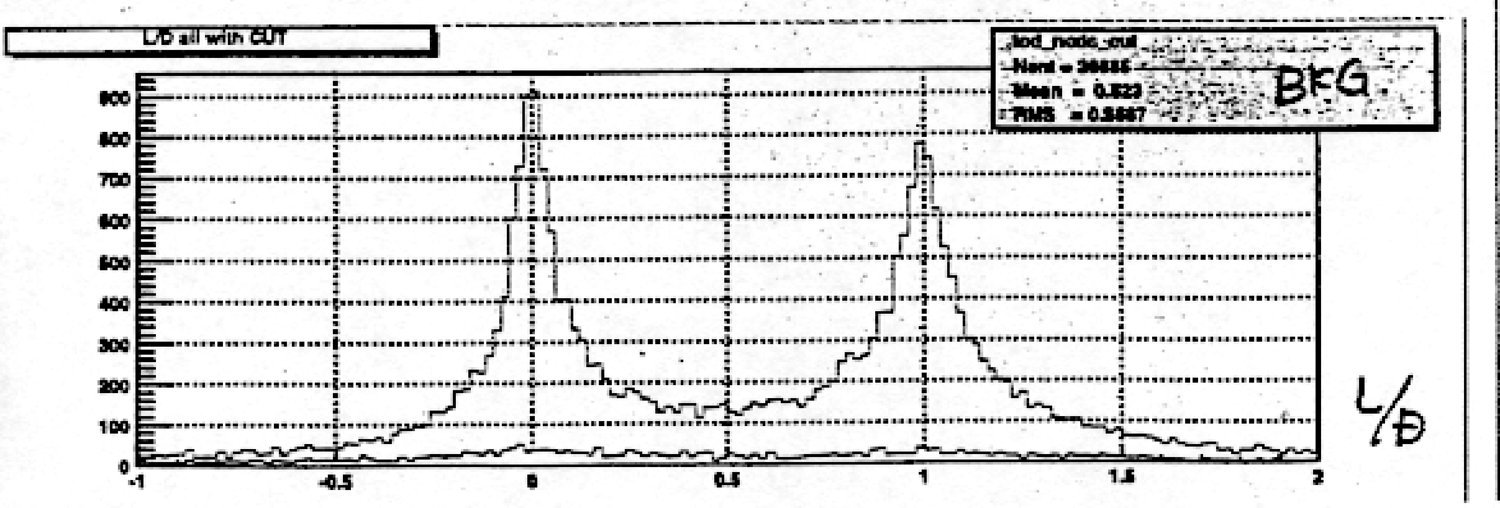


T. Abe

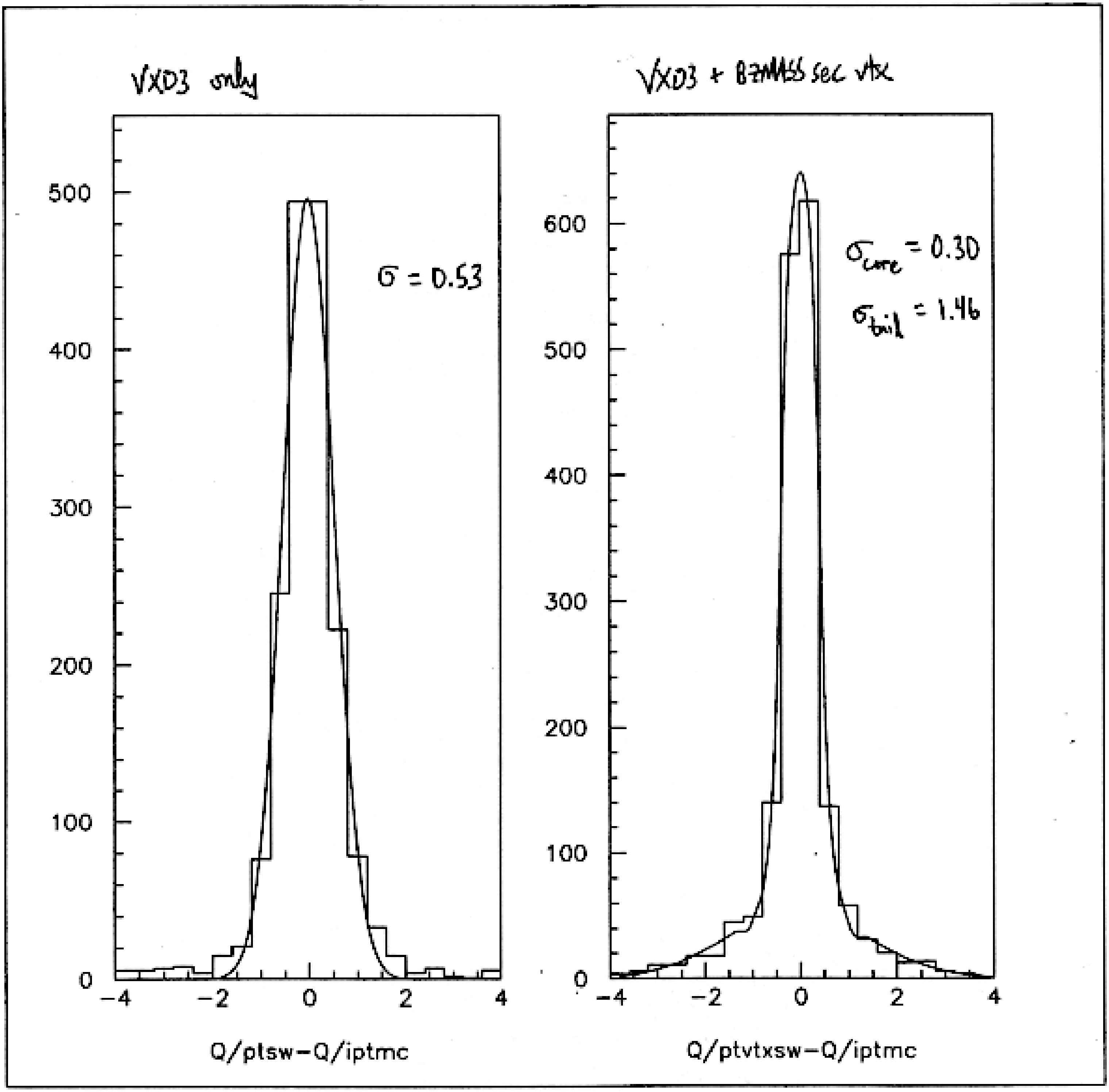

track. (using VXD3-only curvature)
Secondary vertex
L
D
IP


L/D all with CUT
lod_nodc_cut
Mean = 0.523
RMS = 0.5887
IP
L/D


L/D all with CUT
lod_nodc_cut
Mean = 0.523
B/D
L/D

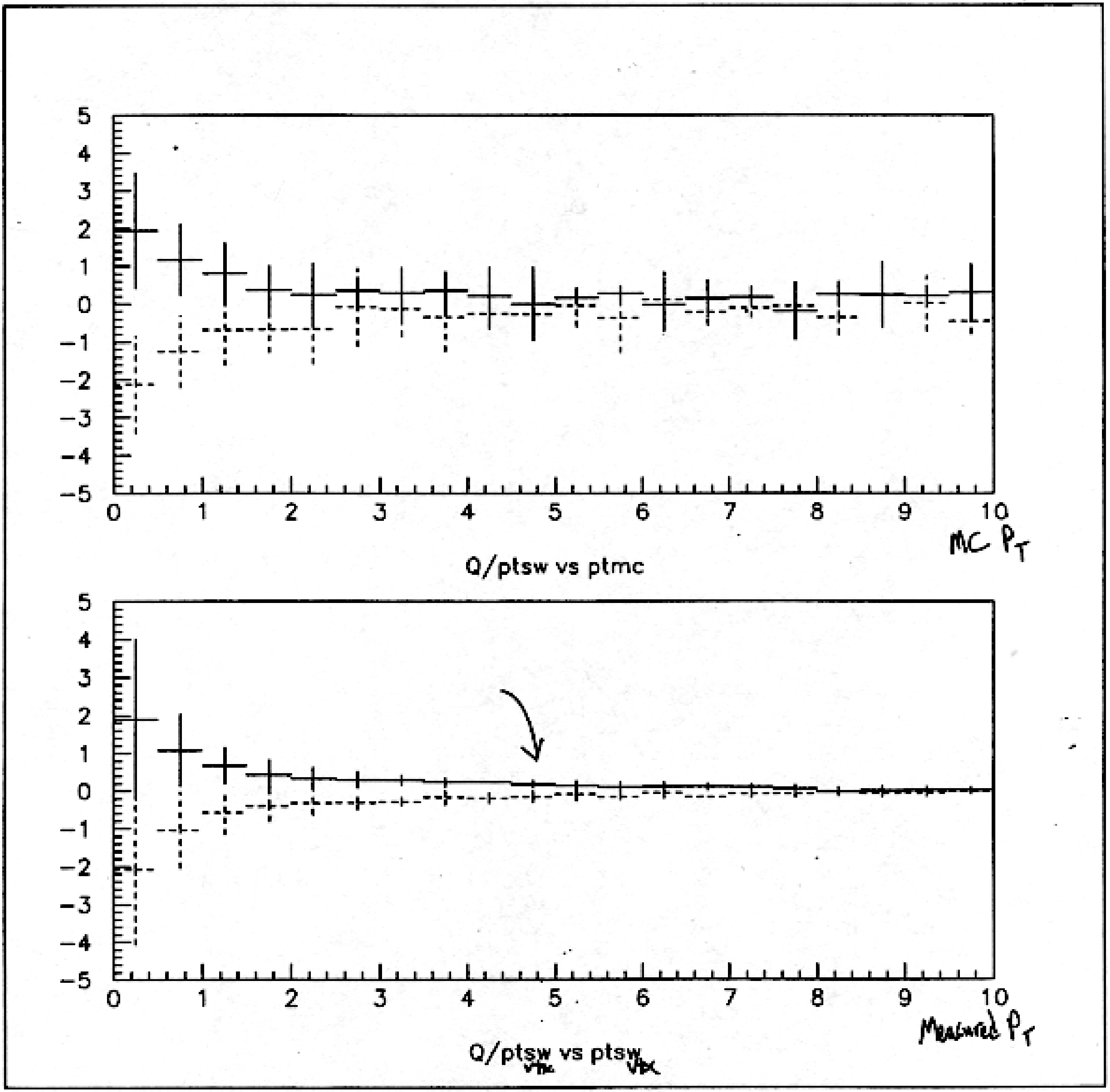

L/D all with CUT
lod_nodc_cut
Mean = 0.523
BKG.
L/D

$\frac{Q}{p_T}$ residuals for PHVXDVs



PHVXOV + BZMASS vtx Charge Separation

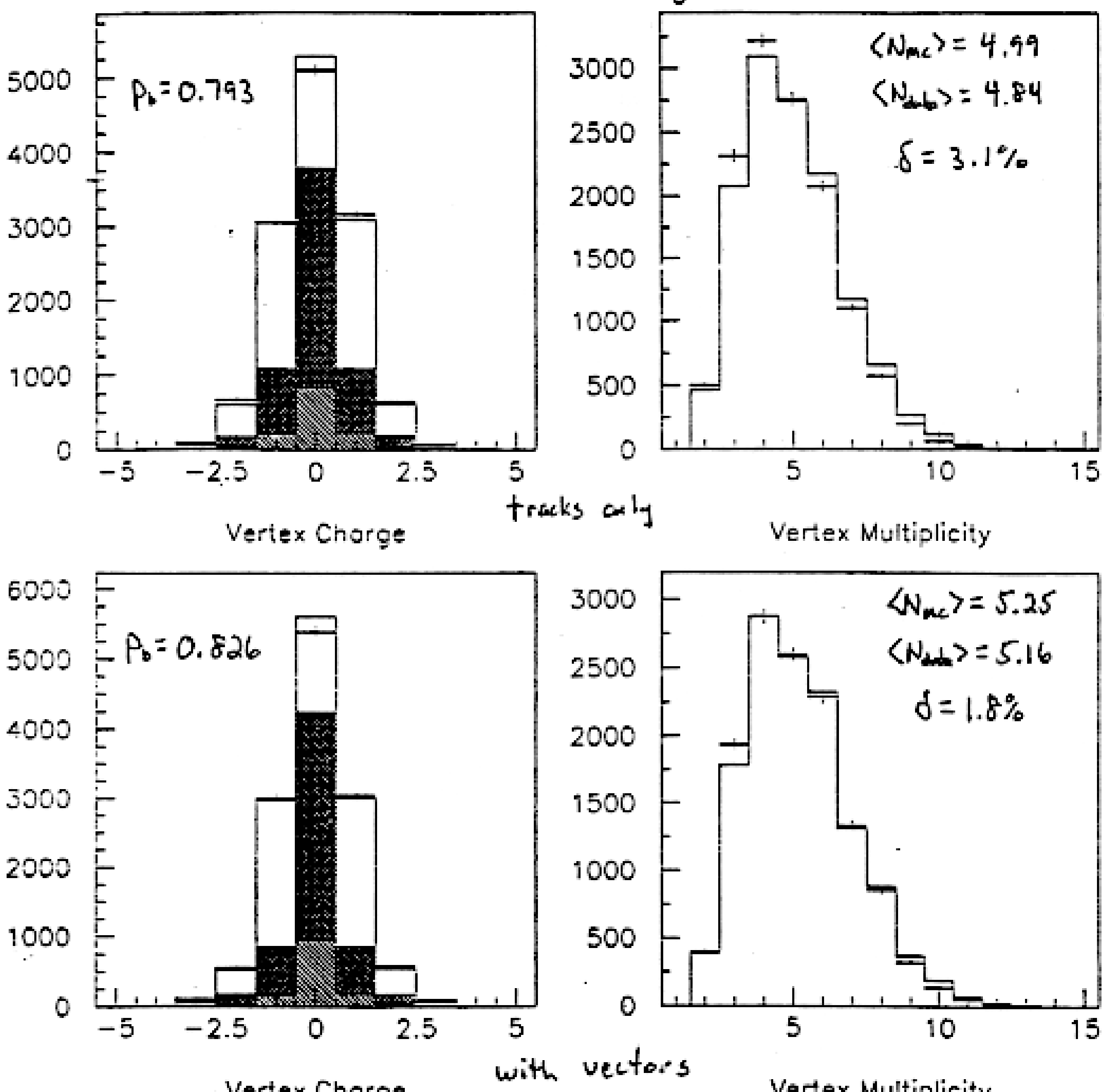
$p_{T_{vtxswim}} > 0.25$ Ge



T. Wright

Using Neural Net PHVXOV attachment to sec. vtx.

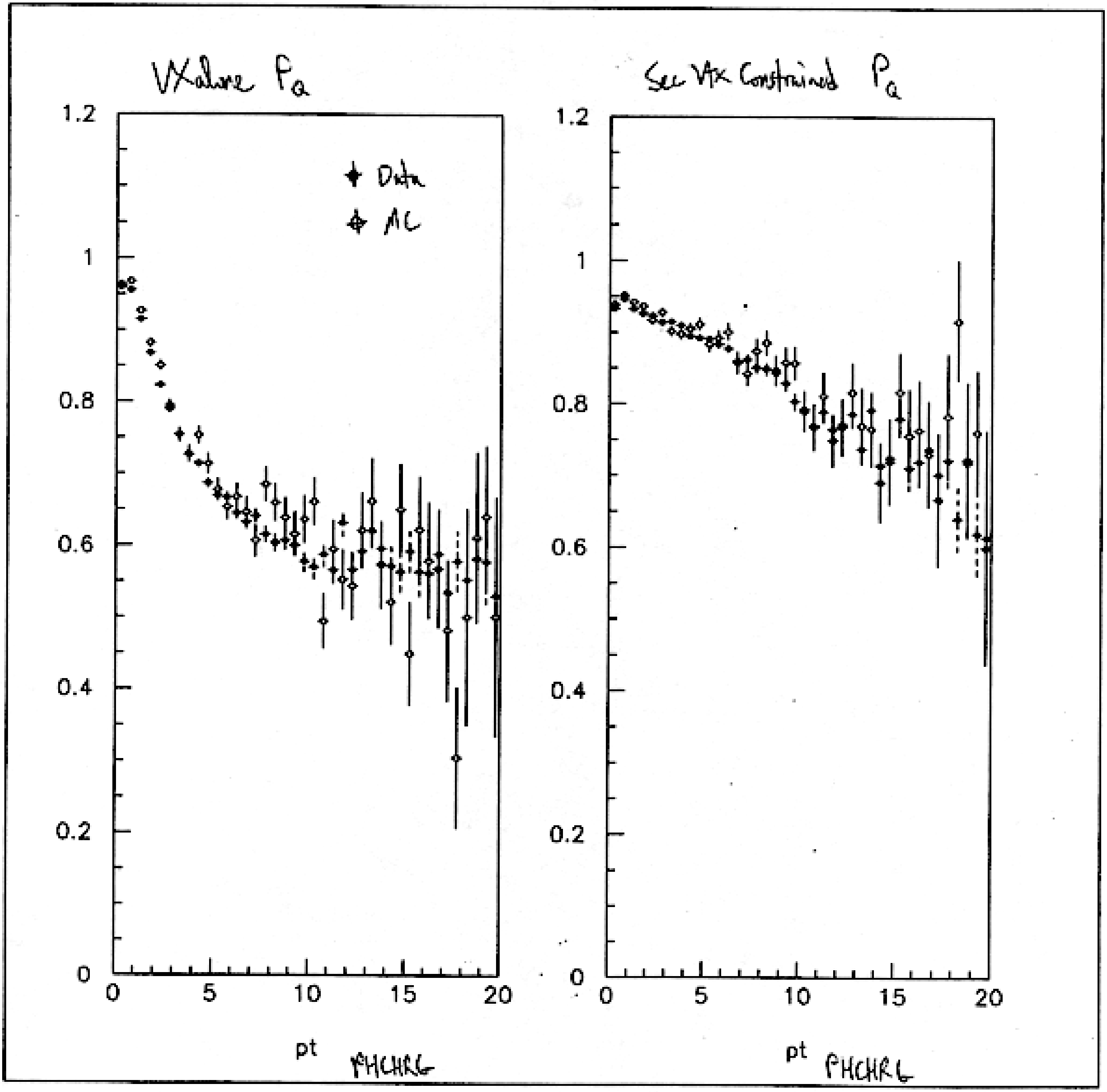
Bottom Tag



⇒ PHVXOV partially fixes tracking efficiency discrepancy

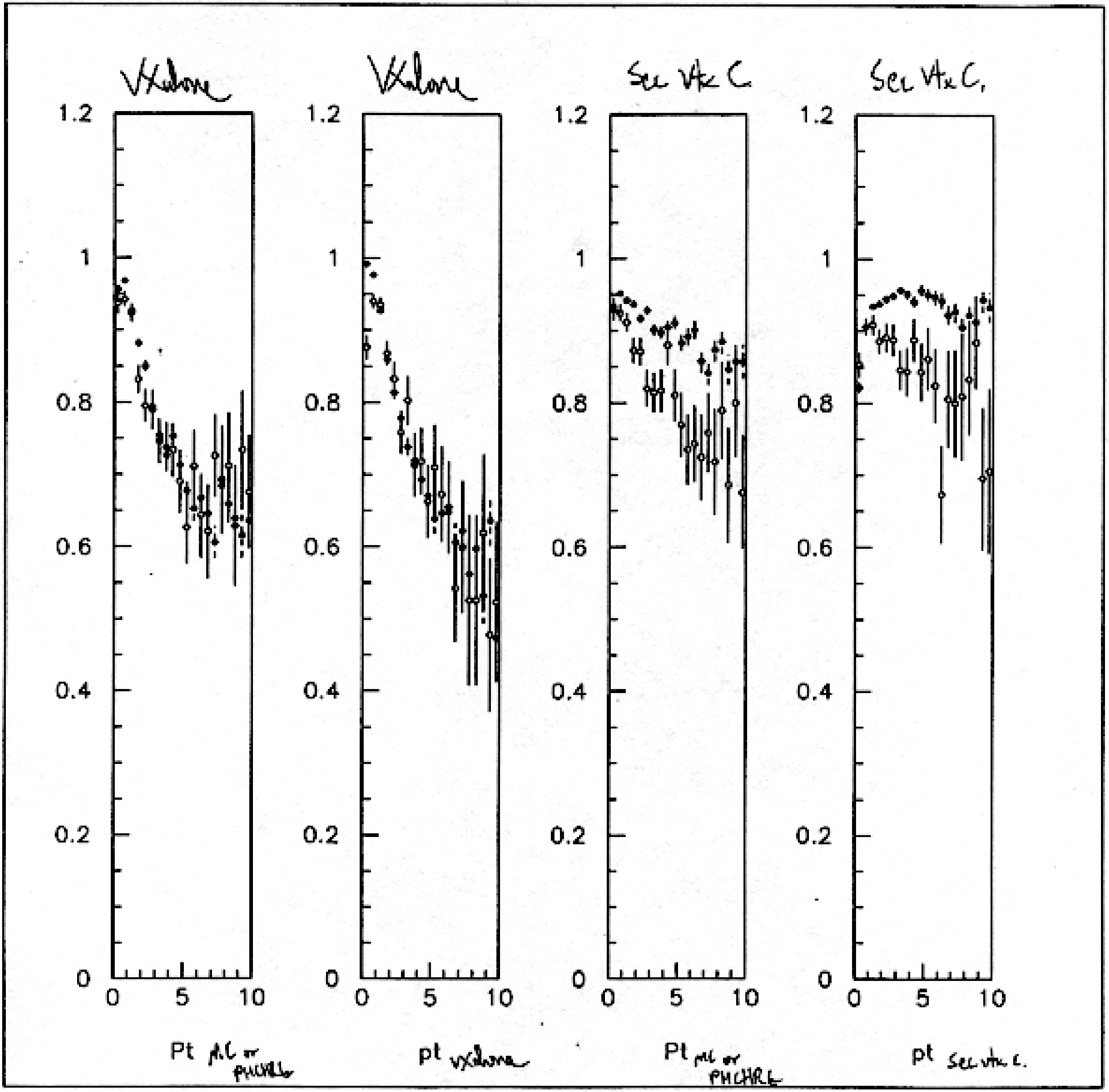
VXOV

Fixed Charge Purity vs P_T using Prev. linked trks



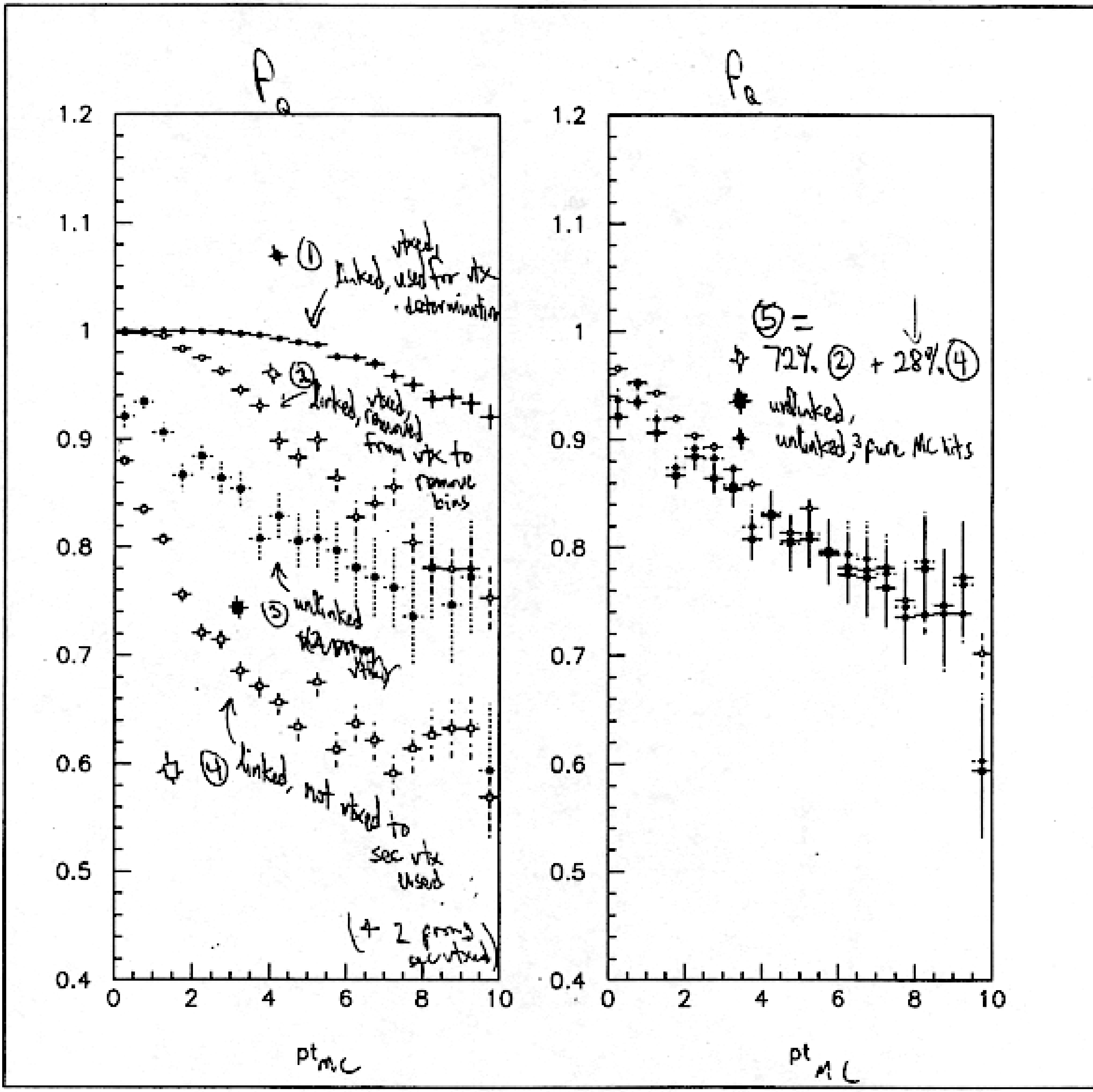
Comparison of Charge Mass Purity for

+ linked PHVXOVS
◇ unlinked PHVXOVS



PHUXOV sec vtx const. Charge Purity vs true P_T for various samples

MC



odel: Sample ② is like a tracking inefficiency causing tks to be missing from sec vtx

Sample ④ " " " for tracks not put on sec. vtx

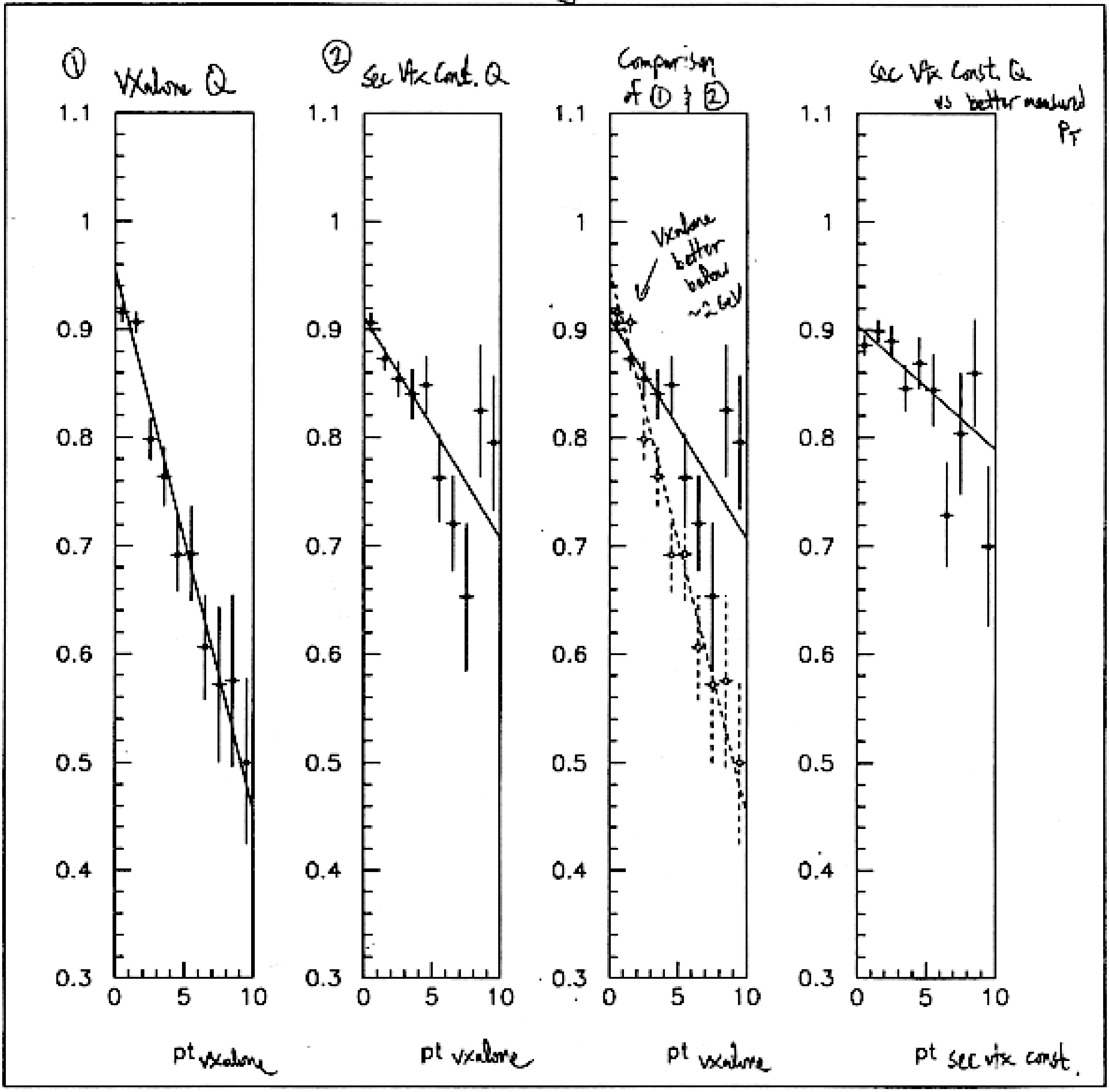
For regular linked tracks $\frac{\#①+②}{\#①+②+④} = .72$, $\frac{\#④}{\#①+②+④} = .28$

⇒ Assume these vtxed, nonvertexed fractions are the same for recovered PHUXOV tks for plot ⑤

Fixed VXOV Charge Purity vs Measured P_T

using vertexed, unlinked PHVXOVs

MC



Fits:

$$P_{vxalone} \simeq 0.954 - 0.050\, P_{T\,vxalone}$$

$$P_{svc} \simeq 0.904 - 0.011\, P_{T\,svc}$$

$$\simeq 0.911 - 0.020\, P_{T\,vxalone}$$

Still need to average in ~ 2% Fakes with P = 0.5

Re-linking the vectors (BBVLINK)

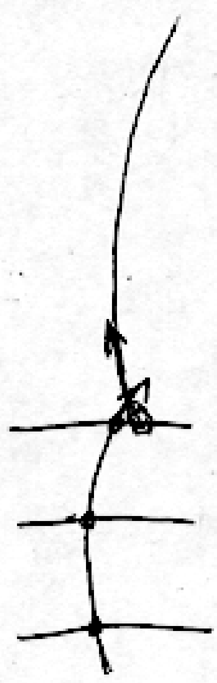
(Leon)

→ PHVXOV charge resolution is very poor at high momentum since the tracks are straight.

→ Momentum measurement is very poor for all vectors.

⇒ Try to link orphaned vectors with unlinked PHCHRG tracks.

First attempt: Compare PHVXOV and PHCHRG track parameters at the outermost VXD3 hit.



Make link if position and direction residuals are small.

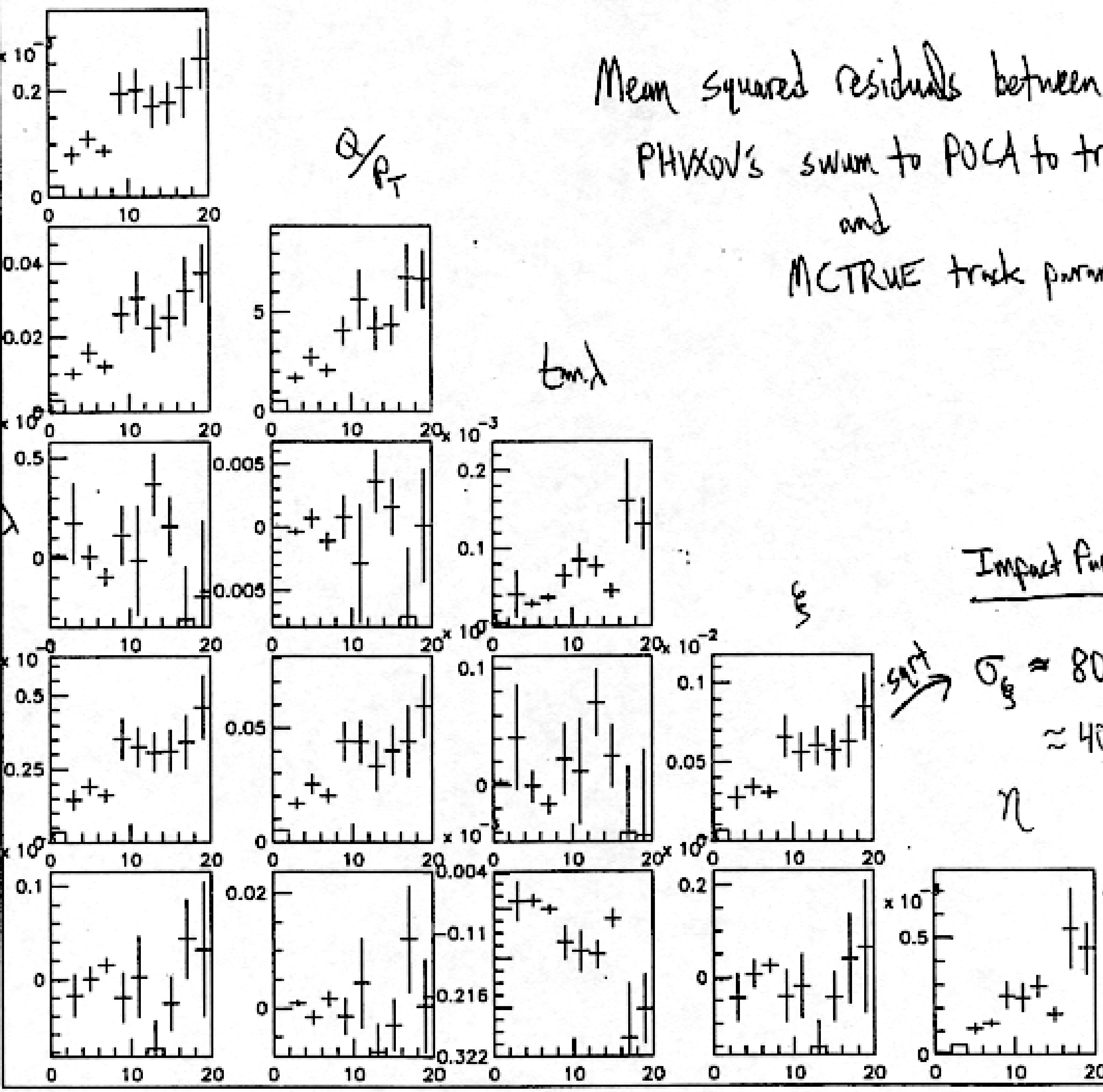
Get 15% of PhVXOVs with 100% charge purity.

⇒ Increases overall P by ~ 2%.

Covariance vs $\frac{1}{p_{MC}^2 \cos^2\lambda_{MC}}$ Final

~~[illegible]~~

Mean squared residuals between PHVXOV's swum to POCA to true origin and MCTRUE track parameters



Impact Param Res

sqrt → $\sigma_\xi \approx 80-180\ \mu m$

$\approx 40\ \mu m,\ p_T > 1$

$\sigma_\eta \approx 40-120\ \mu m$

$\approx 15\ \mu m,\ p_T > 1$

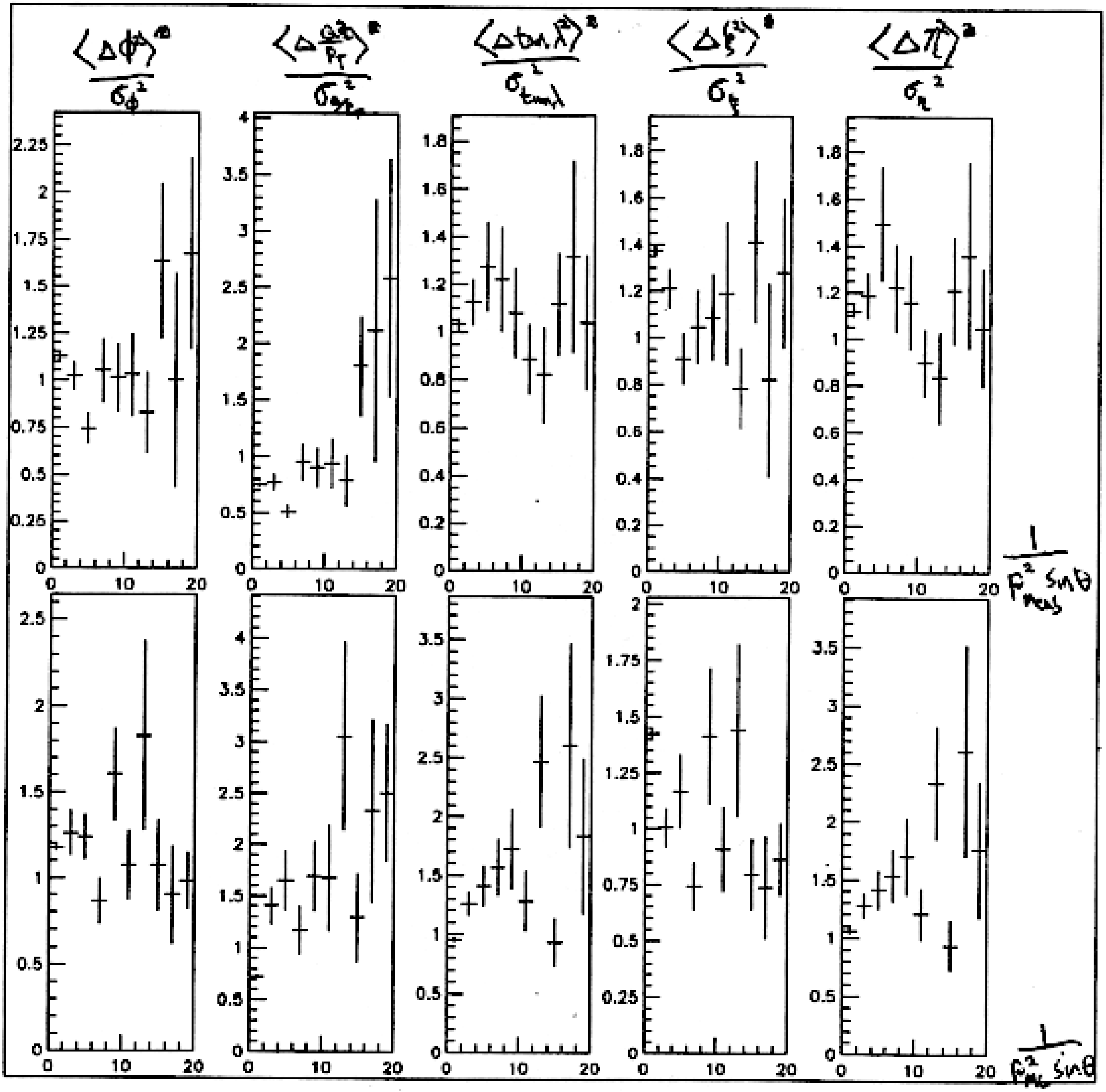
Correlations

$\Delta\phi \sim s \cdot \Delta \frac{Q}{p_T}$ s = arclength

$\Delta\xi \sim s \cdot \Delta\phi \sim s \cdot \Delta\phi_0 + s^2 \Delta \frac{Q}{p_T}$

$\Delta\eta \sim s \cdot \Delta \tan\lambda$

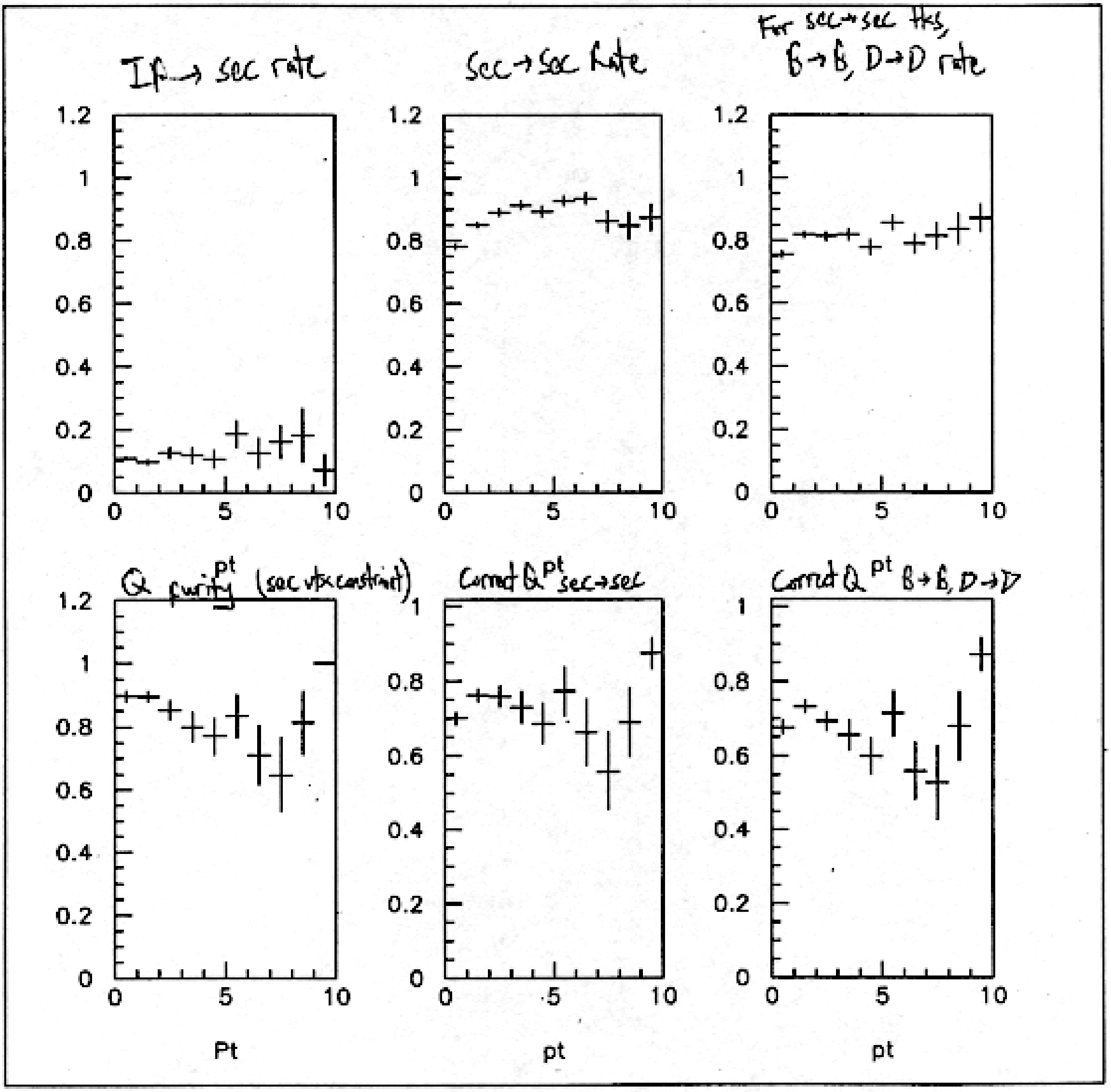
Normalized Mean Squared Residuals vs $\frac{1}{p^2 \sin\theta}$



Using Ad Hoc correction to errors.

(correct initial σ_ϕ, σ_{q/p_T}, $\sigma_{\tan\lambda}$, Let σ_ξ and σ_η fix themselves)

Track Attachment



The Impact Param errors are so large that VXDVs do not often form their own new 1-prong vtx. They get absorbed into pre-existing ones.

↳ When they do, the vtx is not a good estimator of the true decay pos.

Summary:

Next time, give me a

longer lever arm!

— Charge measurement is understood and parameterizable

— Vertexing performance is marginal.

- VXOVs can distinguish between pre-existing B, D vertices but are often consistent with both
- VXOVs rarely form good new vertices.